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Tree Dynamics in Seral and Stable Aspen Stands of Central Utah

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THE AUTHORS

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RESEARCH SUMMARY

Changes in tree number and basal area were examined in 48 aspen *(Populus tremuloides)* stands after 8 years on the Wasatch Plateau, central Utah. The number of trees declined in the aspen stands where the conifers were not increasing (stable), but basal area did not change during this period. In seral stands both number of aspen trees and basal area decreased while conifers increased in both number and basal area. Some conifer reproduction did appear in the stable stands, but survival rate was low. A difference in structure observed between stands dominated by white fir *(Abies concolor)* and stands dominated by subalpine fir *(Abies lasiocarpa)* was linked to stand age. Rates of increase in conifer basal area were not much different between stands dominated by white fir and those dominated by subalpine fir, but the rate of increase in conifer tree numbers was nearly double in the stands supporting white fir. Rate of aspen tree loss in the stands supporting white fir was nearly three times the rate of loss in stands supporting subalpine fir.

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INTRODUCTION

Aspen *(Populus tremuloides)* is the most widespread tree species on the North American continent (Fowells 1965). This feature of aspen has contributed to conflicting hypotheses about its role in plant communities. Generally, aspen forests are considered seral to conifers over much of their range (Baker 1981, Shirley 1941); however, aspen forests are also noted for their stability in Canada (Bird 1930, Moss 1932) and the western United States (Fetherolf 1917, Sampson 1916, Langenheim 1962). Management practices in the aspen ecosystem are influenced by the successional status of aspen, as well as the rate of succession, since many of the range, wildlife, and watershed attributes of aspen stands are greatly diminished as conifers become established.

Our objectives are to determine changes in stand structure and growth rates in both rapidly seral and relatively stable aspen stands. This comparison was made possible by the remeasurement of permanent plots established by K. T. Harper for studying aspen succession.

STUDY AREA

The study location is on the Manti-Lasal National Forest, mostly within the Great Basin Experimental Range in central Utah. Within 4.5 airline miles, the terrain rises 3,500 ft (1 067 m) through oakbrush-aspen, aspen, spruce-fir, and alpine vegetation associations (Keck 1972).

Elevations of the study sites range from about 8,200 to 10,000 ft (2 500 to 3 050 m). Slopes vary from 0 to 60 percent. The general aspect is westward, but slopes exist with nearly every exposure. The soils range from residual clays to sandy clay loams derived from limestone and sandstone parent materials.

The average annual precipitation varies from 16 inches (41 cm) at the 7,100 ft (2 160 m) elevation to nearly 40 inches (102 cm) at the 10,300 ft (3 140 m) elevation. Only about 15 percent of the annual precipitation falls during the summer growing seasons; this amount varying widely at the same location from year to year. Summer storms are intense, usually brief, and fall on a small area. Rates of 2.2 inches (5.6 cm) per hour have been recorded for 20-minute periods (Keck 1972).

STUDY METHODS

Twenty-four pairs of stable and seral aspen stands with similar fire history, distance to conifer seed source, and location were selected in 1969 on the Wasatch Plateau above Ephraim, Utah. The criterion for designating a stand as seral or stable was based on conifer reproduction. Seral stands had vigorous and abundant conifer reproduction; stable stands had little or no conifer reproduction and some aspen reproduction, yet were within 100 ft (30 m) of a conifer seed tree. Within each stand, a 1/10-acre (1/25-ha) macroplot homogeneous in respect to vegetation, topography, and soils was sampled. Diameters at breast height (d.b.h.) were measured on all trees over 4 inches d.b.h. (10.2 cm). Age was recorded for the tallest tree of each species on each plot. Trees less than 4 inches d.b.h. (10.2 cm) were counted on 10 microplots, 1/1000 acre (4 m^2) in size, systematically located on the 1/10-acre (1/25-ha) macroplot. In 1977, the plots were remeasured in the same manner as in 1969.

For analysis, the seral aspen plots were stratified by the predominant conifer on the plots, either white fir *(Abies concolor)* or subalpine fir *(Abies lasiocarpa)*. The stable plots were stratified according to the associated seral plot. Number of trees and basal area

per acre were summarized by 1-inch (2.54-cm) size classes on each macroplot. The size class designation denotes the smallest diameter included in the size class (for example, the 6-inch [15.24 cm] size class includes all diameters from 6.0 to 6.9 inches [15.24 to 17.53 cm]). Microplot data were summarized by number of trees in less than 1 ft, 1 to 6 ft, and 6 ft tall to 4-inch (<0.3 m, 0.3 to 1.8 m, and 1.8 m tall to 10.16-cm) d.b.h. size classes to evalute tree reproduction for each plot. Differences in tree numbers and basal area between the 1969 and 1977 data were used to evaluate growth rates.

The **t** statistic for paired observations was used to evaluate sample differences for the same macroplots in different years. The general **t** statistic for unpaired means was used to evaluate the differences between seral and stable aspen stands (Ostle and Mensing 1963). Only **t**-values larger than tabular values in the 0.05 probability column were declared statistically significant.

RESULTS AND DISCUSSION

Aspen-White Fir Stands

The stable stands selected in the white fir zone range in elevation from 7,800 to 9,000 ft (2 375 to 2 740 m) with slopes from 4 to 45 percent. Exposure generally ranges northeast to northwest with one plot nearly due south. The seral aspen stands in the white fir zone range in elevation from 7,800 to 8,900 ft (2 375 to 2 710 m). Slopes range from 45 to 50 percent.

Numbers.—The number of trees (d.b.h. >4 inches [10.2 cm]) in stable aspen stands declined 10 percent between 1969 and 1977 (table 1). Most of the losses were in the smaller d.b.h. size classes. The number of aspen trees under 4 inches d.b.h. (10.2 cm) did not change significantly between 1969 and 1977 on the stable plots. There may have been an increase in aspen in the two size classes less than 6 ft (1.8 m) tall, but large variations in the number of trees under 4 inches d.b.h. among the stands masked the effect. Conifer reproduction occurs, but most trees are under 1 ft (0.3m) tall and only one conifer has survived to reach tree size in the stable aspen stands.

The number of aspen trees (d.b.h. >4 inches [10.2 cm]) in the seral aspen stands declined 20 percent while the number of conifer trees increased 17 percent between 1969 and 1977 (table 1). In terms of stand composition (table 2), the relative number of aspen trees declined about 6 percent while white fir increased 6 percent in number of trees over the 8-year period. The rest of the conifers showed little change in relative composition. The number of aspen less than 4 inches d.b.h. in the seral stands was not significantly different from that in the stable stands, except for the class over 6 ft (1.8 m) tall which was lower (table 1). Conifers less than 1 ft (0.3 m) tall were numerous in 1969 in the seral stands, but in 1977 showed a tenfold decrease, probably due to yearly variation in conditions necessary for seedling germination. Conifer numbers in the category with height over 6 ft (1.8 m), but less than 4 inches (10.2 cm) d.b.h. were not particularly abundant and, as in the 4- and 5-inch (10.2- and 12.7-cm) d.b.h. size classes, they may be showing the effects of competition from the mature conifers.

The number of aspen trees (d.b.h. >4 inches [10.2 cm]) in stable stands decreased at a rate of 1.3 percent per year (table 3). In seral stands the rate of loss in aspen trees was 2.5 percent per year or about double that observed in the stable stands. Conifer numbers increased at a rate of 2.1 percent per year in the seral stands.

Basal Area:—The stable aspen stands did not change significantly in aspen basal area between 1969 and 1977 (table 4). In contrast, aspen basal area decreased in the seral aspen stands and conifer basal area increased between 1969 and 1977. The relative stand basal area of aspen declined 10 percent over the 8-year period in the seral stands (table 2). White fir basal area increased 8 percent during that period.

The rate of loss in aspen basal area was 1.3 percent per year in the seral stands (table 3). In contrast, conifer basal area increased at a rate of 5 percent per year, with white fir alone increasing 6.4 percent per year.

The seral aspen stands had a greater total basal area than the stable aspen stands because of the conifers. In the stable stands, the lack of change in basal area with the concomitant decrease in trees seems to indicate a maturing and stabilizing of the aspen forest. The decrease in aspen basal area and increase in conifer basal area in the seral aspen stand is viewed as the normal pattern of succession to conifers.

Table 1.—Average number of trees per acre on stable and seral plots associated with the aspen-white fir and aspen-subalpine fir cover types, 1969 and 1977

Reproduction class	Stable aspen							
	Aspen-white fir				Aspen-Subalpine fir			
	Aspen		Conifer		Aspen		Conifer	
	1969	1977	1969	1977	1969	1977	1969	1977
<1 ft	50	345	555	185	46	136	268	4
1 ft-6 ft	245	495	15	15	108	418	11	7
6 ft-4 in	485	550	15	—	354	343	—	—
Tree d.b.h.								
4	222	191	—	—	144	126	—	—
5	122	116	—	—	96	99	—	—
6	89	73	T[1]	—	82	75	—	—
7	66	55	—	—	36	42	—	—
8	39	41	—	T	23	25	—	—
9	19	22	—	—	16	19	—	—
10	15	12	—	—	14	16	—	—
11	9	9	—	—	7	5	—	—
12	5	7	—	—	11	13	—	—
13	3	2	—	—	6	4	—	—
14	2	3	—	—	6	6	—	—
15	1	2	—	—	4	4	—	—
16	2	—	—	—	2	4	—	—
17	—	2	—	—	4	2	—	—
18	1	—	—	—	i	2	—	—
19	1	1	—	—	—	—	—	—
20	—	1	—	—	—	—	—	—
>21	—	—	—	—	—	—	—	—
Tree total[2]	596	536	—	—	452	442	—	—
(Trees/ha)	*(1473)*	*(1324)*			*(1117)*	*(1092)*		

Reproduction class	Seral aspen							
	Aspen-white fir				Aspen-subalpine fir			
	Aspen		Conifer		Aspen		Conifer	
	1969	1977	1969	1977	1969	1977	1969	1977
<1 ft	100	315	6390	685	107	300	5096	800
1 ft-6ft	105	175	150	185	118	375	233	221
6 ft-4 in	120	110	65	36	307	164	114	64
Tree d.b.h.								
4	156	115	24	18	133	111	28	28
5	166	134	22	19	74	69	19	23
6	114	80	22	23	50	48	22	16
7	80	70	9	20	39	40	24	16
8	19	26	11	14	26	21	14	18
9	11	10	7	7	15	16	18	16
10	7	4	5	9	17	14	12	17
11	1	3	6	8	8	6	8	11
12	2	1	5	7	7	6	6	11
13	—	—	—	4	11	6	6	8
14	2	1	—	2	6	5	3	4
15	1	1	1	—	6	5	1	3
16	—	1	—	—	1	1	1	—
17	—	—	2	1	1	1	1	2
18	—	—	—	1	—	—	1	2
19	—	—	—	1	1	1	—	1
20	—	—	1	—	1	1	—	—
>21	—	—	3	4	—	—	—	—
Tree total[2]	559	446	118	138	396	351	164	176
(Trees/ha)	*(1381)*	*(1102)*	*(292)*	*(341)*	*(978)*	*(867)*	*(405)*	*(435)*

[1]T = less than 0.5

[2]Total is for trees >4 inches (10.2 cm) d.b.h.

Table 2.— Percent composition of seral aspen cover types for 1969 and 1977 in two forest types

	Aspen-white fir				Aspen-subalpine fir			
	Tree numbers		Basal area		Tree numbers		Basal area	
Species	1969	1977	1969	1977	1969	1977	1969	1977
Aspen	83	77	70	60	71	67	64	56
White fir	13	19	18	26	T[1]	T	1	1
Subalpine fir	1	1	1	1	26	29	30	37
Blue spruce[2]	3	3	11	13	1	1	2	2
Engelmann spruce[3]					1	1	2	2
Douglas-fir[4]	T	T	T	T	2	2	2	3
Conifer	17	23	30	40	29	33	36	44

[1]T =trace; less than 1 percent.
[2]*Picea pungens.*
[3]*Picea engelmannii.*
[4]*Pseudotsuga menziesii.*

Table 3.— Rate per year change in tree numbers (number/yr) and basal area (ft^2/yr) for seral and stable aspen

	Aspen-white fir				Aspen-subalpine fir			
Category and	Tree numbers		Basal area		Tree numbers		Basal area	
Species	Per yr	%/yr	Ft^2/yr	%/yr	Per yr	%/yr	Ft^2/yr	%/yr
Stable plots								
Aspen	-7.5	-1.3	0.4	0.3	-1.6	-0.4	-0.8	0.7
Seral plots								
Aspen	-14.1	-2.5	-1.4	-1.3	-5.6	-1.4	-1.4	-1.2
White fir	2.1	2.3	1.8	6.4				
Subalpine fir					1.1	.7	1.8	3.4
Blue spruce	.3	1.5	.4	2.4				
Englemann spruce					.1	1.4	.2	4.3
Douglas-fir					.0	.0	.2	3.6
Total conifer	2.5	2.1	2.3	5.0	1.3	.8	2.2	3.4

Table 4.—Basal area (ft^2/acre) on stable and seral aspen plots associated with the aspen-white fir and aspen-subalpine fir cover types in 1969 and 1977

	Aspen-white fir						Aspen-subalpine fir					
	Stable aspen		Seral aspen				Stable aspen		Seral aspen			
	Aspen		Aspen		Conifer		Aspen		Aspen		Conifer	
d.b.h.	1969	1977	1969	1977	1969	1977	1969	1977	1969	1977	1969	1977
4	21.6	20.4	15.5	12.6	2.7	2.0	14.0	13.4	13.0	12.0	2.7	3.1
5	18.1	18.2	24.7	21.4	3.7	3.1	14.1	15.9	11.0	11.1	2.8	3.7
6	18.8	16.6	24.0	18.3	3.7	5.1	17.4	17.0	10.5	10.8	4.7	3.7
7	18.6	16.3	22.6	20.8	2.6	5.9	10.4	12.0	10.9	11.9	6.8	4.8
8	14.3	15.8	6.9	9.8	4.1	5.4	8.3	9.4	9.6	7.9	5.2	7.1
9	8.9	10.8	4.9	4.8	3.2	3.3	7.7	8.9	7.0	7.6	8.5	7.8
10	8.5	7.0	4.0	2.6	2.8	5.4	8.1	9.7	9.9	8.5	8.1	10.2
11	6.1	6.3	.7	2.1	4.0	5.7	4.9	3.7	5.4	4.6	4.4	8.1
12	4.1	8.2	1.6	.8	4.0	6.0	9.3	11.1	5.7	5.4	4.7	9.1
13	3.0	2.0	—	—	—	3.9	5.6	3.6	10.1	6.4	6.0	7.8
14	2.2	3.4	2.1	1.1	—	1.2	6.2	6.5	7.1	5.6	3.1	4.1
15	1.2	2.5	1.2	1.3	1.3	—	5.5	4.5	7.1	6.5	.9	3.7
16	2.9	—	—	1.4	—	—	3.0	5.1	2.1	1.0	4.5	—
17	—	3.2	—	—	3.3	1.7	5.7	3.7	2.4	1.1	1.3	2.4
18	1.9	—	—	—	—	1.8	1.3	2.8	—	—	1.3	3.8
19	2.1	2.1	—	—	—	2.0	—	—	1.4	1.4	—	1.5
20	—	2.3	—	—	2.2	—	—	—	1.6	1.6	—	—
21	—	—	—	—	9.1	12.7	—	—	—	—	—	—
Total	132.3	135.1	108.1	97.0	46.7	65.2	121.5	128.0	114.8	103.4	65.0	81.0
(m^2/ha)	*(30.4)*	*(31.0)*	*(24.8)*	*(22.3)*	*(10.7)*	*(15.0)*	*(27.9)*	*(29.4)*	*(26.4)*	*(23.7)*	*(14.9)*	*(18.6)*

Aspen-Subalpine Fir Stands

The stable and seral aspen stands selected in the subalpine fir zone range in elevation from 8,600 to 10,500 ft (2 620 to 3 200 m). Exposures tend to be northeast to northwest at the lower elevations and southeast to southwest at the higher elevations. Slopes range from 2 to 45 percent.

Numbers.—The number of aspen trees (d.b.h. >4 inches [10.2 cm]) in the stable stands did not change significantly between 1969 and 1977 (table 1.) Aspen reproduction in the 1- to 6-ft (0.3- to 1.8-m) class increased significantly between 1969 and 1977. Conifer reproduction was present in the stable stands, but showed little tendency to grow taller than 6 ft (1.8 m).

The number of aspen trees (d.b.h. >4 inches [10.2 cm]) in the seral stands decreased about 11 percent during the 8-year period while the number of conifer trees (d.b.h. >4 inches [10.2 cm]) increased about 6 percent (table 1). In terms of stand composition, the relative number of aspen trees decreased 4 percent between the 2 years and conifer trees increased 4 percent (table 2). The decline in aspen tree numbers generally appeared to be in the 4-, 5-, and 6-inch (10.2-, 12.7-, and 15.2-cm) d.b.h. size classes. Most of the conifers that established on the plots were subalpine fir. The number of aspen less than 1 ft (0.3 m) tall increased significantly between 1969 and 1977 (table 1). Conifers under 1 ft (0.3 m) tall were numerous in both years, but were most abundant in 1969. The decreasing number of conifer regeneration in successively larger size classes in both 1969 and 1977 seems to be related to high mortality rates in the early years of life.

Aspen tree numbers declined at a rate of 1.4 percent per year in the seral aspen stands, but did not change in the stable stands (table 3). Conifer numbers increased at 0.8 percent per year on the seral stands.

Basal area.—There was no significant change in total basal area in the stable stands between 1969 and 1977. There was, however, a general shift to larger size classes (table 4). In the seral stands, the aspen decreased significantly and conifer basal area increased significantly between 1969 and 1977. The decline in aspen basal area in the seral stands appears to be generally spread across all d.b.h. size classes. In terms of stand composition, the relative basal area of aspen trees decreased 8 percent between 1969 and 1977, and conifer increased 8 percent with subalpine fir accounting for most of the conifer increase (table 2). Aspen basal area declined between 1969 and 1977 at a rate 1.2 percent per year on the seral stands, while conifer basal area increased at a rate of 3.4 percent per year (table 3).

Aspen-White Fir Versus Aspen-Subalpine Fir

The seral aspen-white fir stands have more aspen trees (mostly in the 4- to 7-inch [10.2-to 17.8-cm] d.b.h. size classes) than do the seral aspen-subalpine fir stands (table 1); however, the aspen-subalpine fir stands have more aspen trees over 8 inches (20.3 cm). Conifer trees are more abundant in the aspen-subalpine fir stands than in the aspen-white fir stands (table 1). This trend generally holds over all conifer d.b.h. size classes but especially so in the larger d.b.h. size classes.

There was little difference in the total basal area of aspen between the two seral types (table 4). In 1977, about 75 percent of the aspen basal area however was in the smaller (4- to 7-inch [10.2- to 17.8-cm]) d.b.h. size classes in the white fir stands, while in the subalpine fir stands only about 45 percent of the aspen basal area was in these smaller d.b.h. size classes. Conifer basal area was larger in the aspen-subalpine fir stands than in the aspen-white fir stands. In 1977, conifer basal area was about equal in the seral types in the 4- to 7-inch (10.2- to 17.8-cm) d.b.h. classes, but there was more conifer basal area in the subalpine fir type in the larger size classes.

Because the conifers in the aspen-subalpine fir stands were older than conifers in the aspen-white fir stands, some of the structural differences between the types can be explained. The average age of the oldest subalpine fir was about 83 years, the average age of the oldest white fir, 58 years (table 5). The age for the subalpine fir coincides with a period of very heavy grazing on the Wasatch Plateau (Keck 1972). Such heavy grazing ceased shortly thereafter, and may have released the conifers by reducing trampling and utilization.

Differences in ages between the conifers in the subalpine fir and in the white fir stands may also have been influenced by fuel wood and timber harvesting activities. In about 1920, the Forst Service began to control and manage these activities. The difference could also be related to patterns in fire suppression. The average age of the oldest aspen tree was greater in the seral aspen-subalpine fir stands than in the seral aspen-white fir stands (table 5). This difference in age may relate to the burning history of much of this country and to the likelihood that the higher subalpine fir stands did not burn as often as the lower white fir stands.

Management Alternatives

Aspen forests are ideal for wildlife, watershed, range, and recreation, and the deleterious effect that conifer succession over the long term has on these values suggests that management practices (such as burning, spraying, or cutting) that maintain aspen would be beneficial. A discussion of ecological trends for these values in aspen is included in Harniss (1981). The differing successional rates for the white and subalpine fir stands suggested by the basal area and number of trees infer that the associated conifers should be considered in the selection of aspen stands for manipulation. Removal of conifers from the aspen-subalpine fir stands would maintain multiple use values longer because of slower encroachment of fir and spruce.

The consequences of letting succession proceed to conifers would negatively affect range, water, recreation, and wildlife values. Understory production may be reduced more than one-half when conifer basal area increases to 20 ft^2 (1.9m^2) per acre (Harper 1973). Assuming average values for conifer basal area and age (table 5) and that an exponential curve would approximate conifer growth over time (Ward and Bartos 1981), 20 ft^2 (1.9 m^2) of conifer basal area would occur in about 50 years in the white fir stands and about 67 years in the subalpine fir stands. Water yields are expected to decrease 5 percent as conifer succession occurs and replaces the aspen-oak forests of the Unita Mountains (Harper 1981). Because plant diversity and production are much less in conifer than in aspen stands, wildlife habitat is reduced. Many recreational activities are linked to the aspen forest.

Clearcutting of aspen-conifer stands, possible for fuel wood, in small 1- to 4-acre patches would decrease the conifers and rejuvenate the aspen. Setting the aspen back to the suckering stage would be desirable in many mature aspen stands where more wildlife habitat

Table 5.—Average age of oldest tree in the stable and seral aspen types

	Age[1]			
	Aspen-white fir		Aspen-subalpine fir	
Tree	Stable	Seral	Stable	Seral
Aspen	126.0 ± 19.4[1]	121.9 ± 9.0[1]	140.6 ± 37.3[1,2]	162.7 ± 37.3[2]
Conifer		58.6 ± 14.0[1]		83.4 ± 20.0[2]

[1]Age ± standard deviation; numbers that differ in same row are significant at 0.05 level.

is desired. Selective cutting of the conifers early in succession for Christmas trees or poles would maintain an aspen stand and the related multiple-use values.

Burning is a management alternative in aspen-conifer because (1) it is a natural process that has occurred many times in the aspen ecosystem, (2) its effects and patterns are beneficial for many multiple-use values, and (3) it is relatively inexpensive.

Spraying might be a valuable tool if used on high quality multiple-use sites in areas that are not visible and not accessible to or little used by the public. Time of spraying might be used to selectively kill only conifers or aspen or both conifers and aspen. Spray concentration might be adjusted to obtain a certain percent kill or perhaps to initiate suckering by weakening the overstory aspen.

On sites where the conifers timber growth and value is high and the other resources values are secondary, succession should be accelerated by eliminating the aspen.

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Changes in tree number and basal area were examined in 48 aspen *(Populus tremuloides)* stands after 8 years on the Wasatch Plateau, central Utah. The number of trees declined in stable aspen stands, but basal area did not change during this period. In the seral stands, number of aspen trees and basal area decreased while conifers increased in number and basal area. Some conifer reproduction did appear in the stable stands, but survival rate was low. A difference in structure between stands dominated by white fir *(Abies concolor)* and stands dominated by subalpine fir *(Abies lasiocarpa)* was linked to stand age. Rates of increase in conifer basal area were not much different between stands dominated by white fir or by subalpine fir, but the rate of increase in conifer tree numbers was nearly double in the white fir stands. Rate of aspen tree loss in the white fir stands was nearly three times greater than the rate of loss in the subalpine fir stands.

KEYWORDS: stable aspen, seral aspen, succession, Utah,tree numbers, tree basal area, stand dynamics

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